3.27 ANGLE TRACK

The angle track function in ESAMS is simulated by transfer functions that represent the antenna servos used to reposition the antenna boresight in azimuth and elevation based on the current boresight position, angle rates, and measured angle errors. A number of different angle tracking transfer functions are used in ESAMS from the generic “Improved Type I” and “Type II” servos which have the general form:

$$H(s) = \frac{\beta^2 + \gamma^2}{\alpha} \frac{s + \alpha}{s^2 + 2\beta s + (\beta^2 + \gamma^2)} \qquad [3.27\text{-}1]$$

to system-specific transfer functions which have been derived from exploitation measurements. For SAM systems simulated with the generic servos, the constants, α, β, and γ are selected to best fit performance estimates for the specific threat simulated.

3.27.1 Objectives and Procedures

The objective of this analysis was to examine the effect of varying the servo filter characteristics on the overall radar tracking and missile flyout performance. The angle tracking servo type is specified by the RDRD variable, IASTYP, and the appropriate angle update subroutines are called from UPD8AG. The analysis approach was to change the filter type by changing the value of IASTYP.

The system selected for this analysis uses IASTYP=9 as the default which calls threat-specific angle filters modeled in subroutines SVOAZ5 and SVOEL5. Prior versions of ESAMS used IASTYP=7 for this radar. This study compares IASTYP=9 with IASTYP=7 and 4.

The step response for each of the angle tracking filters was computed by developing off-line drivers for the appropriate ESAMS subroutines. The model was then run with different values of IASTYP and the tracking errors in azimuth and elevation and missile flyout trajectories were compared. The tracking errors are obtained from logical unit 50 and the missile flyout trajectories are printed in the standard output file.

3.27.2 Results

The response of the angle filters to a step input is plotted in Figure 3.27-1. The rise and settling time for the GHK filter, IASTYP=4, is fastest, followed by the filter for IASTYP=9, then the filter for IASTYP=7.

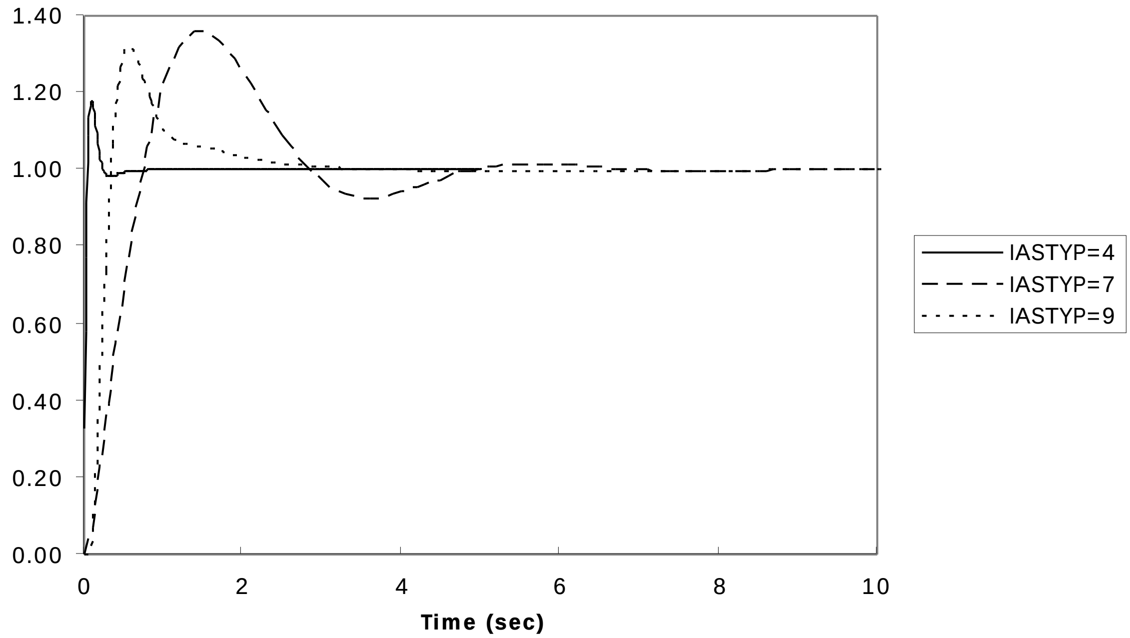

FIGURE 3.27-1. Step Response for Angle Filters used in the Sensitivity Analyses.

Target tracking and missile flyout performance were compared for one intercept geometry in which the target started at an uprange of 2500 m and flew by the SAM site at a constant speed and offset of 250 m/s and 4000 m, respectively. With this engagement geometry, the azimuth angle rate passes through a maximum at 10 sec when the target reaches its closest point of approach to the SAM site. This interval in the profile should be the most stressing for the angle track filter.

One interesting and counter-intuitive result was that the track servo with the fastest response (IASTYP=4) had the most difficulty tracking the target. The radar broke lock shortly after missile launch and the engagement was aborted. The radars with IASTYP=7 and 9 both tracked the target to intercept; however, only the radar with the IASTYP=9 angle filter resulted in an intercept.

In order to improve the tracking capability of the GHK filter (IASTYP=4), the gain was decreased from the default value of 0.28 to 0.028 and 0.0028. Decreasing the gain has the effect of slowing the response time, and the corresponding step response curves are plotted in Figure 3.27-2. With a gain of 0.028 the GHK filter tracked for several seconds before breaking lock, and with a gain of 0.0028, it tracked for the duration of the missile engagement. For the subsequent track error and missile flyout comparisons, a gain of 0.0028 was used in the GHK filter.

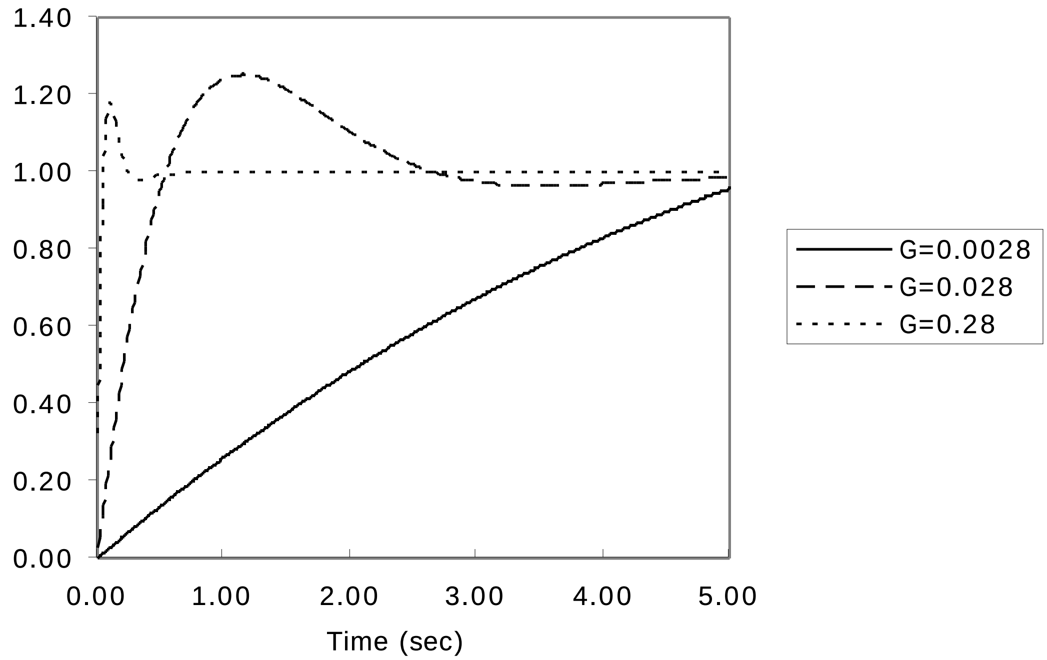

FIGURE 3.27-2. Step Response Curves for GHK Filter (IASTYP=4) with Different Gains.

The azimuth and elevation tracking histories corresponding to these three filter types are plotted in Figures 3.27-3 and 3.27-4. One can observe that all three filters require several seconds before the transients settle out and that the radars with IASTYP=7 and IASTYP=4 exhibit significantly large error buildup, particularly around 10 sec when the azimuth rate is reaching a maximum. The radar with IASTYP=9 tracks with virtually no angle error after a settling time of about 3 sec.

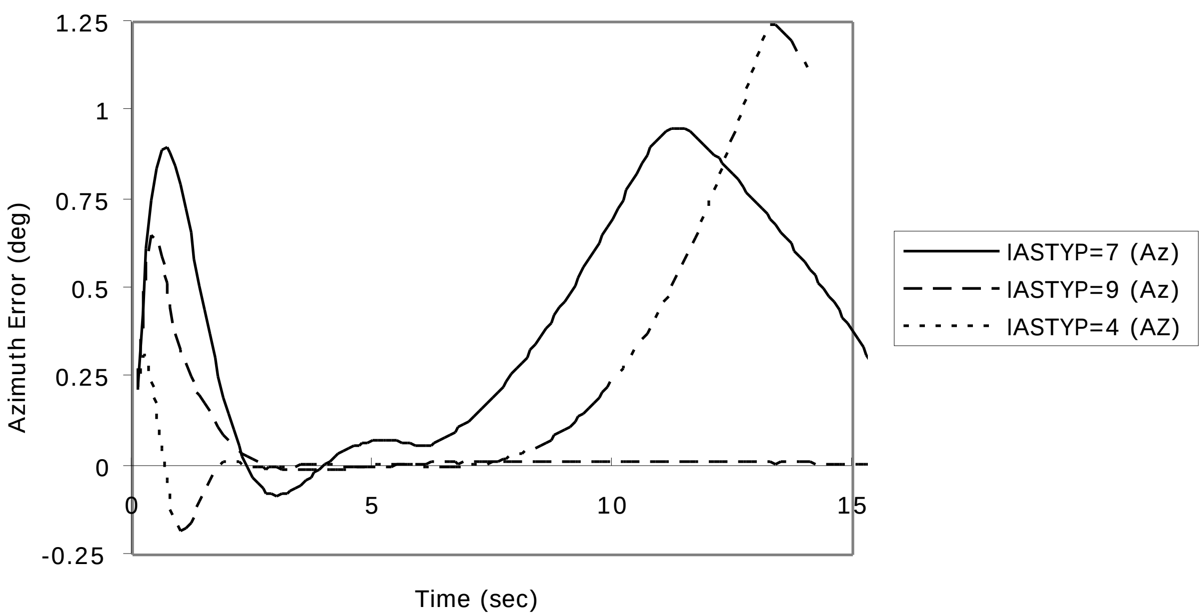

FIGURE 3.27-3. Target Tracking Errors in Azimuth for Different Angle Tracking Servos.

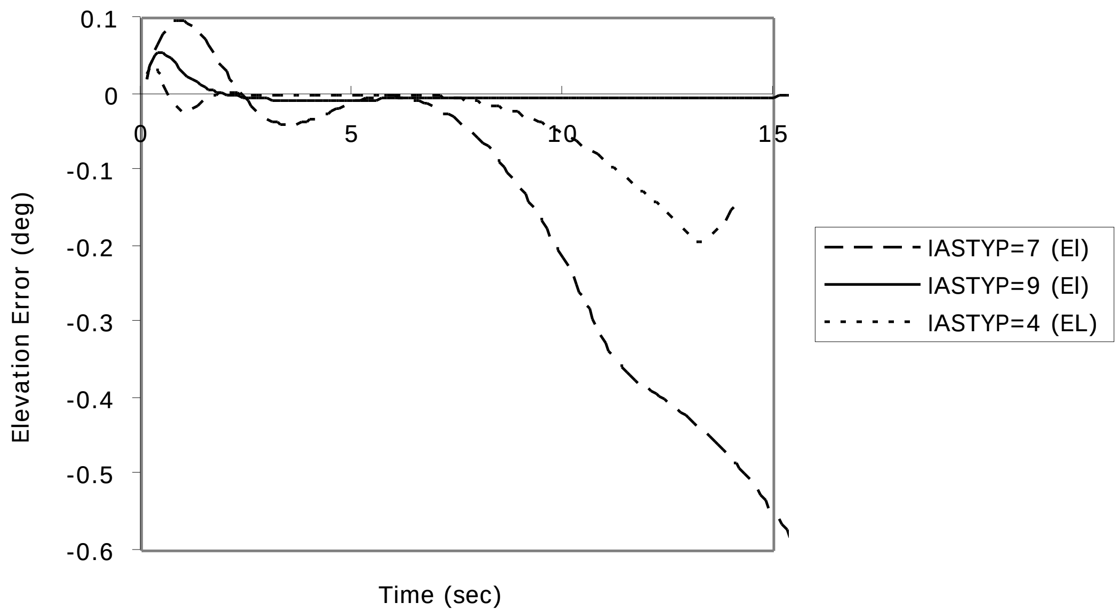

FIGURE 3.27-4. Target Tracking Errors in Elevation for Different Angle Tracking Servos.

The effect of the three angle track filters on missile flyout performance is compared in Figures 3.27-5 and 3.27-6. Figure 3.27-5 compares the ground track of the missile flyout and Figure 3.27-6 compares the altitude profile as a function of time-of-flight. The missile being guided by the radar with IASTYP=9 turns a little tighter which is a consequence of the smaller azimuth errors. There is also more error in elevation for the IASTYP=7 filter which contributes to the missile missing the target.

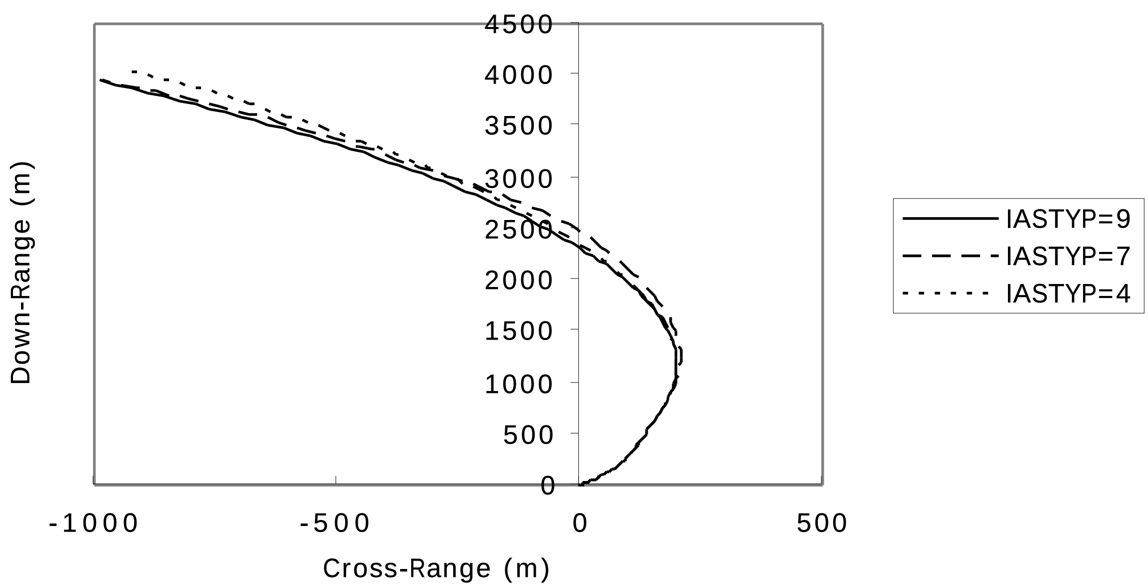

FIGURE 3.27-5. Ground Tracks of Missile Flyout for Different Angle Tracking Servos.

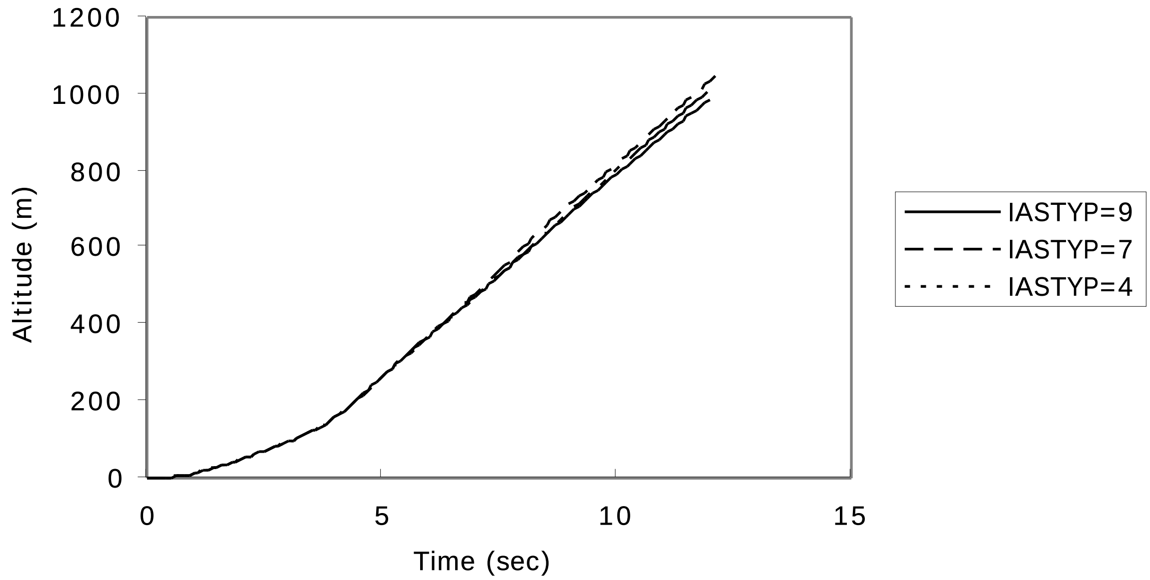

FIGURE 3.27-6. Elevation Profile of Missile Flyout for Different Angle Tracking Servos.

3.27.3 Conclusions

ESAMS appears to be very sensitive to the characteristics of the angle tracking filters. It is not generally true that a filter with a fast response time will track better than a filter with a slower response time. Input data for this FE should be obtained from exploitation testing in which the filter response to ramp and step function inputs are measured. An appropriate data collection interval is on the order of 5% of the filter rise time for a step input.